# EXPLORING WIND ENERGY Teacher Guide

Hands-on activities that provide a comprehensive understanding of the scientific, economic, environmental, technological, and societal aspects of wind energy to secondary students.



GRADE LEVEL Secondary

SUBJECT AREAS
Science
Social Studies
Language Arts
Technology





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# Teacher Advisory Board Vision Statement NEED Mission Statement

The mission of the NEED Project is to promote an energy conscious and educated society by creating effective networks of students, educators, business, government and community leaders to design and deliver objective, multi-sided energy education programs.

In support of NEED, the national Teacher Advisory Board (TAB) is dedicated to developing and promoting standards-based energy curriculum and training.

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# **EXPLORING WIND KIT: \$425.00**

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1 Anemometer 1 Wind Gauge 1 Wind Vane

1 Genecon and Book

1 Box Snow Cone Cups

2 Multimeters

1 Compass

Large Straws

**Small Straws** 

30 Binder Clips

100 Straight Pins 30 Pencils **Alligator Clips** Masking Tape **Teacher Guide** 

30 Student Guides

2 - 24" PVC Pipe

2 - 2" PVC Pipe

12 - 6" PVC Pipe

6 – PVC T-Joints (2 with drilled holes)

11 - PVC Elbow (90°) Joints

2 - PVC Couplers

2 – Basic Nacelles (includes generators)

1 - Geared Head Assembly

150 - 1/4" Dowels

10 – 12 Hole Crimping Hub

25 Balsa Sheets 25 Coroplast Sheets

1 Visual Voltmeter

2 Extra Generators

#### **Materials NOT IN KIT**

Foam Cups Scissors Fans Rulers Hole Punch

**Permanent Markers** 

Tape

EXPLORING WIND ENERGY was developed by the NEED Project in cooperation with the KidWind Project with funding from the American Wind Energy Association.







# APPLICABLE NATIONAL SCIENCE EDUCATION CONTENT STANDARDS: 9-12

Science as Inquiry: Content Standard A

Abilities Necessary to do Scientific Inquiry

- Identify questions and concepts that guide scientific investigations.
- Design and conduct scientific investigations.
- Use technology and mathematics to improve investigations and communications.
- Formulate and revise scientific explanations and models using logic and evidence.
- Recognize and analyze alternative explanations and models.
- Communicate and defend a scientific argument.

# Understandings about Scientific Inquiry

- Scientists usually inquire about how physical, living, or designed systems function.
- Scientists conduct investigations for a wide variety of reasons.
- Scientists rely on technology to enhance the gathering and manipulation of data.
- Mathematics is essential in scientific inquiry.
- Scientific explanations must adhere to criteria such as: a proposed explanation must be logically consistent; it must abide by the rules of evidence; it must be open to questions and possible modification; and it must be based on historical and current scientific knowledge.

Physical Science: Content Standard B

Motions and Forces

Electricity and magnetism are two aspects of a single electromagnetic force. Moving electric charges produce magnetic forces, and moving magnets produce electric forces. These effects help students to understand electric motors and generators.

Conservation of Energy and the Increase in Disorder

- The total energy of the universe is constant. Energy can be trasnferred in many ways however, it can never be destroyed.
- All energy can be considered to be either kinetic energy, which is the energy, which is the energy of motion; potential energy, which depends on relative position; or energy contained by a field, such as electromagnetic waves.

Earth and Space Science: Content Standard D

Energy in the Earth System

Heating of the earth's surface and atmosphere by the sun drives convection with-in the atmosphere and oceans, producing winds and ocean currents.

# Science and Technology: Content Standard E

# Abilities of Technological Design

- Identify a problem or design an opportunity.
- Propose designs and choose between alternative solutions.
- Implement a proposed solution.
- Evaluate the solution and its consequences.
- Communicate the problem, process, and solution.

# **Understandings About Science and Technology**

- Creativity, imagination, and a good knowledge base are all required in the work of science and engineering.
- Science and technology are pursued for different purposes. Scientific inquiry is driven by the
  desire to understand the natural world, and technological design is driven by the need to meet
  human needs and solve human problems. Technology, by its nature, has a more direct effect
  on society than science because its purpose is to solve human problems, help humans adapt,
  and fulfuill human aspirations. Technological solutions may create new probelms.

# Science in Personal and Social Perspectives: Content Standard F

# **Natural Resources**

- Human populations use resources in the environment to maintain and improve their existence. Natural resources have been and will continue to be used to maintain human populations.
- The earth does not have infinite resources; increasing human consumption places severe stress on the natural processes that renew some resources, and it depletes those resources that cannot be renewed.

# **Environmental Quality**

 Many factors influence environmental quality. Factors that students might investigate include population growth, resource use, population distribution, overconsumption, the capacity of technology to solve problems, poverty, the role of economic, political, and religious views, and differen ways humans view the earth.

# History and Nature of Science: Content Standard G

# **Historical Perspectives**

• Usually, changes in science ocur as small modifications in extant knowledge. The daily work of science and engineering results in incremental advances in our understanding of the world and our ability to meet human needs and aspirations.

# SECONDARY WIND TEACHER GUIDE

# **BACKGROUND**

Exploring Wind Energy is an inquiry-based unit with teacher and student guide containing comprehensive background information on wind energy and electricity generation. Through hands on inquiry investigations, reading non-fiction text, and critical thinking activities students will learn about the physics of wind, the history of harnessing wind's energy, and how we harness wind's energy today. The kit that accompanies this curriculum contains most of the materials to conduct the activities and investigations. Please refer to page 3 of the Teacher Guide for a complete list of materials included in this kit.

# TIME

The sequence of lessons was designed for a 50 minute class period. In this setting the unit will take 2-3 weeks.

# SCIENCE NOTEBOOKS

Throughout this curriculum science notebooks are referenced. If you currently use science notebooks or journals, you may have your students continue using these. If you do not have science notebooks, a notebook has been built into the student guide for use during this unit. A rubric to guide assessment of student notebooks can be found on page 12 in the Teacher Guide.

In addition to science notebooks, student work pages have been included in the Teacher Guide. Depending on your students' level of independence and familiarity with the scientific process, you may choose to use these to help guide them instead of science notebooks. Or, as appropriate, you may want to make copies of these pages and have your students glue or tape the copies into their notebooks.

# DAY 1

Materials: Science Notebooks

Objective: Students practice making observations using their senses.

# Procedure:

- Have students read the introduction to Beaufort and his scale, page 4 in the Student Guide. Continue reading the selections titled What is Wind? and Global Wind Patterns under the Physics
- 2. Take the class outside so that students can make their own wind observations. In their science notebooks, students should record observations that give them clues about the winds' strength in words and/or sketches.
- 3. After returning to the classroom, have students share their observations with each other, and write a paragraph describing their observations.

#### DAY 2

Materials: For each student or pair - 5 snow cone cups, 1 pencil, 2 straws, 1 straight pin, copies of *Wind Speed Exploration* (Teacher Guide page 13), science notebooks For the class - anemometer, wind gauge, wind vane, compass

Objective: Students build on their experiences from Day 1 to build understanding of measuring wind speed and direction.

#### Procedure:

- 1. Students should read the sections *Monitoring Wind Direction, Wind Velocity,* and *Wind Shear and Turbulence* on page 6 in the Student Guide.
- 2. Students use the directions on *Wind Speed Exploration* to build their own anemometers.
- 3. Teach students how to use their anemometers and other wind measuring tools. Wind Gauge directions are on page 14 of the Teacher Guide.
- 4. Bring students outside with their anemometers, science notebooks, and wind measuring tools included in the kit. If possible, allow students to spread out to different areas of the campus to record wind speed and direction. Students should record data in their science notebooks.
- 5. Return to class and discuss with students their observations. Ask: Were there differences in wind speed around the school grounds? Why might that be?

# DAY 3

Materials: For each student or pair of students - foam cup\*, 1 large straw, 1 small straw, string, paperclips, tape, scissors, copies of *Wind Can Do Work* and *4-Blade Windmill Template* (Teacher Guide pages 15 and 16)
For the class - fan(s)

Objective: Students begin to understand wind's ability to do work.

# Procedure:

- 1. Students read the section titled *Energy* on pages 7-9 in the Student Guide.
- 2. Students build windmills using the Wind Can Do Work directions.
- 3. In science notebooks students should diagram their windmill assembly.
- 4. Students investigate the question, "What is the maximum load that can be lifted to the straw?" Students should record data and observations in their science notebooks.

OPTIONAL EXTENSION: Students can redesign the windmill to see if they can produce more work from the system. They can also think of their own question and design their own investigation based on the system.

<sup>\*</sup>not included in the kit

# DAY 4

Materials: Copies of *History of Harnessing Wind's Energy* worksheet for each student (Teacher Guide page 17)

Objective: Students will know that humans have been using the wind to do work for a long time.

#### Procedure:

- 1. Students read *Evolution of the Windmill* and *American Windmills* on pages 12-13 and the *History of Windpower* on pages 16-18 in the Student Guide.
- 2. Using the *History of Harnessing Wind's Energy* worksheet, students choose five important events and analyze them.
- 3. Next, students choose one event and write a more detailed paragraph about the event in their science notebooks. They should include information on what brought the event about and what impact it had. As an extension, this can be turned into a more in-depth research report.

# DAY 5

Materials: Copies of *Observing a Genecon* worksheet for each student (Teacher Guide page 19), Benchmark Blade Materials (poster board\*, dowels, hubs, glue, tape), at least one turbine tower set up

Objective: Students will understand how electricity is produced.

# Preparation:

- 1. Assemble at least one turbine (you will need both for Day 6) using the directions on pages 22-23 of the Teacher guide.
- 2. Create your own set of benchmark blades, see page 24 for the blade template.
- 3. Familiarize yourself with the Genecon.

# Procedure:

- Students read Electricity on pages 10-11 in the Student Guide.
- 2. Demonstrate with the Genecon the difference between a motor and a generator. Use page 18 in the teacher guide for more detailed instructions. Students can take notes in their science notebooks or use the *Observing a Genecon* worksheet.
- 3. For additional Genecon activities please refer to your Genecon booklet.
- 4. If time allows introduce to students that they will be working on teams to design the most efficient turbine blades possible. To do this they will first investigate isolated variables using "benchmark" blades. It is recommended that all of the students make blades out of poster board (not included in the kit) before changing the blade materials in the fifth blade investigation.

**WIND TURBINE MANAGEMENT TIP:** Your kit has two towers and ten hubs. In your classroom you can set up two testing stations using the towers provided. Each student group should receive their own hub, and they can use this to prepare their blade investigations. When they are ready to test their designs, students can bring their hub over to the tower and connect it to the generator.

**WARNING:** When pulling hubs off of the generator, students need to be careful not to pull the generator out of the nacelle.

<sup>\*</sup> not included in the kit

Materials: 2 wind turbine towers, blade materials\*, tape, multi-meters, hubs, dowels, pennies\*, copies of Blade Investigations (Teacher Guide pages 25-30, optional), science notebooks

Objective: Students investigate the effect of blade variables and design blades to achieve the optimum electrical output.

# Preparation:

- 1. If you haven't done so already, construct the turbine towers as directed on pages 22-23 of the Teacher Guide.
- 2. \*Blade Materials It is recommended that the initial blades be made of poster board which is not included in the kit. Some balsa wood and coroplast sheets have been included in your kit, but anything can be used as blade materials. You may want to gather your own materials, or have students bring some before Blade Investigation #5. Pennies - You will need pennies for Investigation #4.

# Procedure:

- 1. Divide students into small groups. Each group should be given their own hub and blade materials. When groups are ready to test their blades, they can put their hub onto the tower.
- 2. Each day have students complete a blade investigation and read more about wind turbines to learn the science at work. The suggested breakdown of the text is:
  - a. Blade Investigation #1 Modern Wind Machines, page 13
  - b. Blade Investigation #2 Aerodynamics, page 13
  - c. Blade Investigation #3 Wind Turbine Efficiency Betz Limit, page 14
  - d. Blade Investigation #4 Wind Farms, page 14
  - e. Blade Investigation #5 Energy on Public Lands, page 14-15
  - f. Blade Investigation #6 Gearing Up for More Power, page 14

MATH EXTENSION: Have students calculate the power produced by their turbine using the Calculating Wind Power worksheet on page 31.

# **DAYS 11+**

Materials: Siting a Wind Farm Questions (Teacher Guide pages 32-34)

Objective: Students will understand the many different elements to be considered when siting a wind farm.

#### Procedure:

- 1. Read the wind Summary on page 15. Discuss with students their perspective on wind energy.
- 2. Assign students different roles to investigate; decide how much time students will have for research and presentation. Be sure to visit the web resources on your own prior to the activity to best guide your students to relevant and appropriate resources.
- 3. Students research their roles, answer the questions, and assess the positives and negatives or the proposal based on their roles.
- 4. Students present to the class their understandings in a mock town hall meeting. You may have teachers or students from other classes act as community members and vote based on the presentations.

# ADDITIONAL ACTIVITIES

# WIND SURVEY

Materials: Wind Survey

Objective: Students will demonstrate their understanding of wind turbines and wind energy.

#### Procedure:

1. Give students the Wind Energy Survey on page 11 of the Teacher Guide. You may do this at the beginning and end as a pre/post test.

#### ANSWER KEY:

1) c 2) a 3) b 4) a 5) b 6) a 7) b 8) d 9) d 10) a

# LANGUAGE ARTS EXTENSIONS

Online at www.need.org you can find plays and rock song lyrics relating to wind energy, efficiency and conservation, and renewable energy sources. These are fun reinforcement extensions for your class. These materials also provide an outreach opportunity for your students to perform for students at younger levels to help teach them about energy sources. From NEED's homepage, go to the section "For Educators" and then to "Curriculum Materials." Search for these materials by title:

- Energy on Stage
- **Energy Rock Performances**

Name	Date	

# **WIND ENERGY SURVEY**

1. The	e energy of moving n a. potential		es, electrons, ar chanical	nd subs	stances is ca	alled	d. electrical
2. Rei	newable energy sour a. 1%	ces pro b. 5-1	•	entage c. 10-		. energ	
3. The	e energy in wind com a. ocean currents	es fron	n… b. solar radiatio	on	c. jet strear	m	d. climate change
4. The	e direction of a wind labeled a. northwest wind	blowing	g from Chicago t b. southeast w		_		s called a… d. south wind
5. Wir	nd is measured by th a. Doppler Scale	e	b. Beaufort Sca	ale	c. Richter S	Scale	d. Coriolis Scale
6. An	instrument that meas a. anemometer	sures w	vind speed is a b. wind vane	· •	c. multimet	er	d. aerometer
7. A d	evice that uses elect a. motor	romagı	netism to produc b. generator	ce elec	tricity is calle c. electrom		d. turbine
8. A w	a. potential energy b. kinetic energy to c. chemical energy d. kinetic energy to	to elect potenti to kine	al energy tic energy				
9. A g	ood place to site a w a. mountain top b. sea coast c. narrow valley d. all of the above	ind turl	oine could be				
10. W	ind energy produces a. 1.3%	how m	nuch of total eled b. 5.9%	ctricity	generation i c. 0.		J.S. today? d. 19.6%

# **Science Notebook Rubric**

This is a sample rubric that can be used with science notebooks. You may choose to only assess one area at a time or look at an investigation as a whole. It is suggested that you share this rubric with students and discuss the different components.

	Scientific Concepts	Scientific Inquiry	Data/ Observations	Conclusions
4	Written explanations illustrate accurate and thorough understanding of scientific concepts.	The student independently conducts investigations and designs and carries out his or her own investigations.	Comprehensive data is collected and thorough observations are made. Diagrams, charts, tables, and graphs are used appropriately. Data and observations are presented clearly and neatly with appropriate labels.	The student clearly communicates what was learned and uses strong evidence to support reasoning. The conclusion includes application to real life situations.
3	Written explanations illustrate an accurate understanding of most scientific concepts.	The student follows procedures accurately to conduct given investigations, begins to design his or her own investigations.	Necessary data is collected. Observations are recorded. Diagrams, charts, tables, and graphs are used appropriately most of the time. Data is presented clearly.	The student communicates what was learned and uses some evidence to support reasoning.
2	Written explanations illustrate a limited understanding of scientific concepts.	The student may not conduct an investigation completely, parts of the inquiry process are missing.	Some data is collected. The student may lear more heavily on observations. Diagrams, charts, tables, and graphs may be used inappropriately or have some missing information.	The student communicates what was learned but is missing evidence to support reasoning.
1	Written explanations illustrate an inaccurate understanding of scientific concepts.	The student needs significant support to conduct an investigation.	Data and/or observations are missing or inaccurate.	The conclusion is missing or inaccurate.

# **Culminating Project Rubric**

This rubric may be used with the wind siting activity on page 31-33 or any other group work you ask the students to do.

	Content	Organization	Originality	Workload
4	Project covers the topic in-depth with many details and examples. Subject knowledge is excellent.	Content is very well organized and presented in a logical sequence.	Project shows much original thought. Ideas are creative and inventive.	The workload is divided and shared equally by all members of the group.
3	Project includes essential information about the topic. Subject knowledge is accurate.	Content is organized in a logical sequence.	Project shows some original work. Work shows new ideas and insights.	The workload is divided and shared fairly equally by all group members, but workloads may vary.
2	Project includes essential information about the topic, but there are 1-2 factual errors.	Content is logically organized but may have a few confusing sections.	Project provides essential information, but there is little evidence of original thinking.	The workload is divided, but one person in the group is viewed as not doing a fair share of the work.
1	Project includes minimal information or there are several factual errors.	There is no clear organizational structure, just a compilation of facts.	Project provides some essential information, but no original thought.	The worldoad is not divided, or it is evident that one person is doing a significant amount of the work.

# WIND SPEED EXPLORATION

PURPOSE: To make an anemometer to measure wind speed.

MATERIALS: 1 pencil, 5 cone paper cups, 2 long straws, glue, hole punch, scissors, straight

pin, marker, watch with second hand

#### PROCEDURE:

1. Cut the end off one cup to make a hole big enough for the pencil to fit in. Use the hole punch to make four holes in the top of the cup: two holes opposite each other very near the rim and two holes on opposite sides about a half-centimeter below the first holes, as shown in Diagram 1.

- 2. Slide the straws through the holes in the cup, as shown in Diagram 2.
- Use the hole punch to make two opposite holes in the other cups about 1

centimeter from the rim. Slide one cup onto the end of each straw, making sure the cups face in the same direction. Glue the cups to the straws.

Diagram 1

- 4. Center the straws in the cup. Slide the cup over the pencil as shown in Diagram 2 and push the pin through the middle of both straws and into the pencil eraser as far as you can to anchor the apparatus. Lift the straws slightly away from the eraser on the pin so that the apparatus spins easily. You might need to stretch the pin holes in the straws by pulling gently on the straws while holding the pin in place.
- 5. Color one cup so that you can count the revolutions of the anemometer.
- 6. Take your anemometer outside and measure the speed of the wind in several areas around the school by counting the number of revolutions in 10 seconds and using the chart to determine miles per hour (mph). Compare your results with those of others in the class.
- 7. Use the wind gauge to measure the wind speed and compare the results to those of your anemometer.

#### Revolutions mph per 10 sec 2-4 1 5-7 2 8-9 3 10-12 4 5 13-15 6 16-18 19-21 7 22-23 8 24-26 9 10 27-29 30-32 11 33-35 12 36-37 13 14 38-40 41-43 15 44-46 16 17 47-49 50-51 18 52-54 19 55-57 20

#### CONCLUSIONS:

- 1. How did your data compare to that of your class?
- 2. How could you change the design of your anemometer to make it more reliable?

Diagram 2

# WIND GAUGE

This type of wind gauge is designed to measure wind speed based on Bernoulli's principle, which states that energy is conserved in a moving fluid (liquid or gas). If the fluid is moving in a horizontal direction, the pressure decreases as the speed of the fluid increases. If the speed decreases, the pressure increases. This means that as the speed of the wind increases, its presure decreases. Pressure moves from high to low.

The wind gauge has two holes in the top of a hollow stem -

- A. One large hole
- B. One small hole
- C. Two holes on the lower back.
- D. At the bottom of the hollow stem is a very light ball that can move up and down the stem.

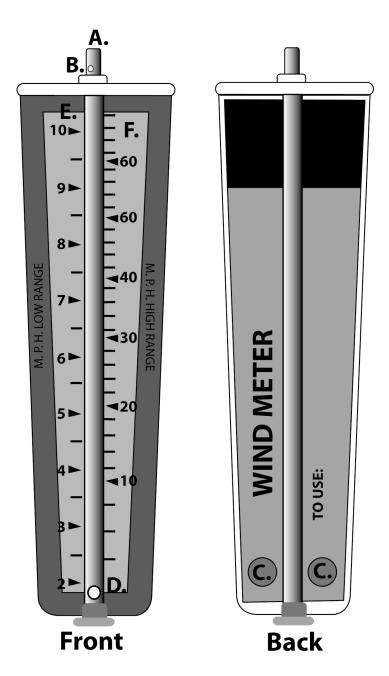
The wind gauge has two ranges -

E. low and

F. high

To operate the wind gauge, hold the wind gauge upright into the wind with the scale side facing you. Do not block the bottom holes on the back. As the wind flows across the top holes it creates lower pressure at the top of the stem. No wind flows across the bottom holes, so the pressure there remains higher than at the top. Air flows into the bottom holes, lifting the ball.

If the wind is blowing faster than 10 mph and the ball is at the top of the stem, cover the large hole at the top of the stem with your finger. Be careful not to obstruct the smaller hole on the side of the stem. The wind will create lower pressure only at the smaller hole. Read the wind speed using the high range on the wind gauge when the top hole is covered.



# WIND CAN DO WORK

QUESTION: What is the maximum load that can be lifted all of the way to the top?

MATERIALS: Windmill Blade Template, one large straw, one small straw, tape, 50 centimeter (cm) thread, paperclips, foam cup, 3 straight pins, binder clip, fan, ruler, hole punch, marker

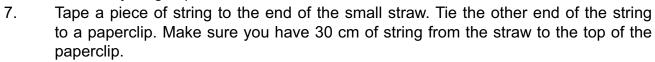
#### PROCEDURE:

1. Turn the cup upside down.

2. Cut the large straw so that you have an 8 cm length, discard the other portion. Tape the large straw horizontally to the bottom of the cup (which is now the top) so that there is an equal amount of straw on both ends. Set this aside.

3. Prepare the windmill blades using the *Windmill Blade Template*.

- 4. Measure 0.5 cm from the end of the small straw and make a mark. Insert a pin through the small straw at this mark. This is the front of the straw.
- 5. Slide the straw through the front of the windmill blades until the pin rests against the blades. Secure the blades by wrapping a piece of tape around the front end of the straw. Insert a second pin directly behind the blades.
- 6. Insert the small straw into the large straw on the cup. Place a pin through the small straw directly after the large straw to hold everything in place.

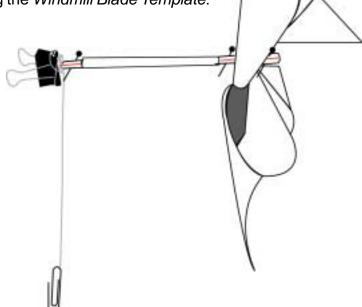




- 8. On the very end of the small straw near where the string is attached, fasten a binder clip in place for balance and to keep the string winding around the straw.
- 9. Investigate: What is the maximum load that can be lifted all of the way to the top? Record your data.

CONCLUSION: In your science notebook, draw a diagram of the system. Label the energy transformations that occured in order for work to take place.

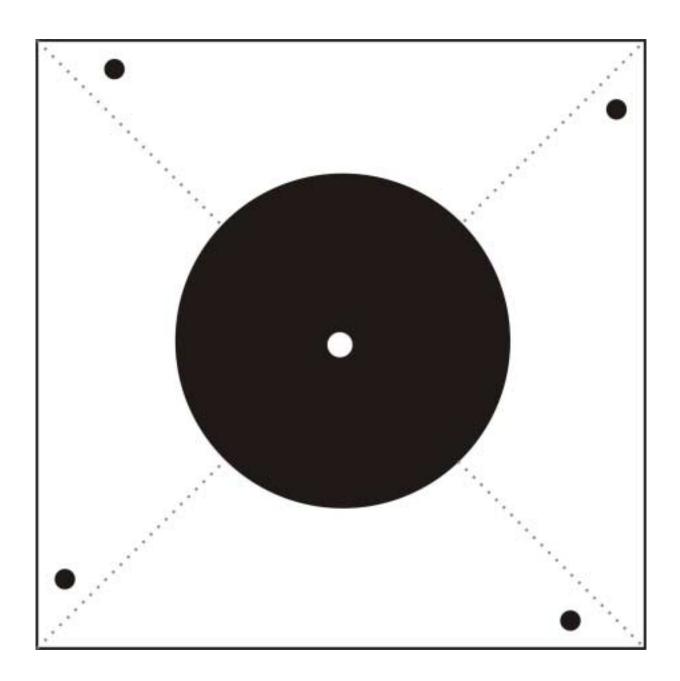
EXTENSION: What variables can you change in this investigation? Create a new investigation changing one variable at a time.



# **4-BLADE WINDMILL TEMPLATE**

# PROCEDURE:

- Cut out the square.
- 2. Cut on the dotted, diagonal lines.
- 3. Punch out the four black holes along the side (being careful to not rip the edges) and the white hole in the center.
- 4. Follow the directions on the "Wind Can Do Work" activity sheet to complete the windmill.



Name<sub>\_</sub>

# History of Harnessing the Wind's Energy

Date\_

What happened as a result?				
How did this event come to be?				
Event				
Date		0	er.	

# **GENECON ACTIVITIES**

#### TEACHER DEMONSTRATION—GENERATOR VS. MOTOR

Activity used with permission from Adventures with the GENECON Hand Operated Generator by Gary W. Nahrstedt.

**OBJECTIVES:** To understand that a generator converts kinetic energy into electrical energy.

To understand that a motor converts electrical energy into kinetic energy.

**MATERIALS:** Genecon with output cord, 1 bulb (3.8V, .3A) in socket with leads, dry cell battery (any

1.5 volt AAA, AA, or D), KidWind turbine, fan

#### PROCEDURE:

#### Part One

- 1. Plug the output cord into the back of the Genecon. Connect the leads of the Genecon to one of the miniature bulb sockets using leads provided in the kit.
- 2. Slowly turn the rotary handle of the Genecon with increasing force until the bulb lights. What do you notice about the bulb? How is it affected by the turning speed of the handle?
- 3. Rotate the handle in the opposite direction. What do you notice?

  Caution: excessively rotating the handle may burn out the bulb or strip the gears damaging the unit.

#### Part Two

1. Replace the light bulb with a dry cell battery, with the two alligator clips making contact with the opposite ends of the battery. Now what happens?

#### Part Three

- 1. Attach the alligator clips from the wind turbine to the leads of the Genecon.
- 2. Face the turbine blades into the fan and watch the Genecon as the turbine blades spin. What happens to the Genecon? Change the speed of the fan faster and slower. What do you notice?

# Background Information: Why does the Genecon work?

In the first part of the demonstration, the Genecon acts as a generator. A generator is a device that converts kinetic energy into electrical energy. When the handle is turned, the bulb lights. You should notice that the bulb becomes brighter as the handle is turned more rapidly. In general, the brighter the bulb, the more voltage the Genecon is producing. The bulb will light when the handle turns in either direction, although the polarity is reversed (See Activity 17 in the Genecon Guide).

In the second part of the demonstration, the Genecon acts as a motor—a device that converts electrical energy into kinetic energy. The battery converts chemical energy into electrical energy to turn the handle (kinetic energy).

In the third part of the demonstration, the Genecon again acts as a motor. Electrical energy from the wall outlet powers the fan (kinetic energy). The wind (kinetic energy) is captured by the turbine blades and they spin (kinetic energy). The spinning motion generates electrical energy that flows through the leads from the turbine to the Genecon. This electrical energy provides the power to turn the handle (kinetic energy). Notice the speed of the turning handle corresponds to the speed of the power source—the spinning blades. A motor and a generator are essentially the same device—the direction of the electrical flow determines what the device is called. Motor: electrical energy in, kinetic energy out. Generator: kinetic energy in, electrical energy out.

#### **Assessment Questions:**

- 1. Lighting the bulb demonstrates a series of energy conversions. Describe as many as you can.
- 2. Write a paragraph describing how a motor works.

# **OBSERVING A GENECON**

What is the difference between a motor and a generator? QUESTION:

O	BS	E	R١	VΑ	ΓIC	λC	IS

OBSERVATIONS 1.	S  How does the speed with which the handle is turned affect the light?
2.	How does reversing the direction of the handle affect the light?
3.	What happens when the Genecon is connected to a battery?
4.	What happens when the Genecon is attached to the wind turbine?
5.	How does the speed of the fan affect the Genecon?
CONCLUSIONS 1.	Define generator and explain how a Genecon is a generator.

2. Define motor and explain how a Genecon is a motor.

# **MEASURING ELECTRICITY**

Included in this kit are three tools to measure electricity, two multimeters and one voltmeter. The multimeter allows you to measure current, resistance, and voltage, and it displays the reading numerically. The voltmeter measures voltage only, but it displays a visual reading as higher electrical outputs illuminate more lights.

When using either meter, it should be noted that some measurements will never "stay still" at a single repeatable value. This is the nature of the variables being monitored in some circumstances. For example, if you were to measure the resistance between your two hands with the Ohm meter setting on the multi-meter (Mega Ohm range—millions of Ohms), you would find that the values would continuously change. How tightly you squeeze the metal probes and how "wet" or "dry" your skin might be can have a sizable effect on the reading that you obtain. In this situation, you need a protocol or standardized method to allow you to record data.

We recommend that you discuss with your class the variability of measurement and let them come up with a standard for collecting data. They may decide to go with the lowest reading, the highest reading, or the reading that appears most frequently in a certain time period.

# DIGITAL MULTIMETER



DC Voltage: Connect RED lead to VI ImA connector and BLACK to COM. Set SWITCH to highest setting on DC VOLTAGE scale (1000). Connect leads to solar panels.

Adjust SWITCH to lower settings until a satisfactory reading is obtained.

DC Current: Connect RED lead to VITIMA connector and BLACK to COM.

Set SWITCH to highest setting on DC CURRENT scale (200m).

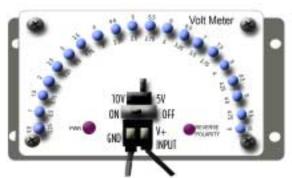
Connect leads to seter panels in series.

Adjust SWITCH to lower settings until a satisfactory roading is obtained.

# BEFORE USING THE MULTIMETER

READ THE OPERATOR'S INSTRUCTION MANUAL INCLUDED IN THE BOX FOR SAFETY INFORMATION AND COMPLETE OPERATING INSTRUCTIONS.

# **VISUAL VOLTMETER**



#### **Directions:**

- 1. Switch the tab over to 5V.
- Press down on the "GND" button. Insert one wire from the turbine into the hole on the bottom. Release the button to secure the wire in place.
- Repeat step two with the other wire on the "V+ Input" side.
- 4. Turn the volt meter on.
- 5. Place the turbine in front of the fan. The lights on the volt meter will light indicating how much electricity is being generated.

\*If the "Reverse Polarity" light flashes, switch the wires in the "GND" and "V+ Input" locations.

# BASIC MEASUREMENT VALUES IN ELECTRONICS

Symbol	Value	Meter	Unit
E	Voltage (the force)	Voltmeter	Volts
I	Current (the flow)	Ammeter	Amps/Amperes
R	Resistance (the anti-flow)	Ohmmeter	Ohms

1 Ampere = 1 coulomb/second

1 Coulomb = 6.24 x 10<sup>18</sup> electrons (about a triple axle dump truck full of sand where one grain of sand is one electron)

# **Prefixes for Units**

# **Smaller**

(m)illi x 1/1000 or .001

( $\mu$ ) micro x 1/1000000 or .000001

(n)ano x1/100000000 or.000000001

(p)ico x 1/100000000000 I or .000000000001

# **Bigger**

(**K**)ilo x 1,000

(**M**)ega x 1,000,000

(**G**)iga x 1,000,000,000

# FORMULAS FOR MEASURING ELECTRICITY

The formula pie works for any three variable equation. Put your finger on the variable you want to solve for and the operation you need is revealed.

**Series Resistance** (Resistance is additive)

$$R_{T} = R_{1} + R_{2} + R_{3} + R_{n}$$

Parallel Resistance (Resistance is reciprocal)

$$1/R_T = 1/R_1 + 1/R_2 + 1/R_3 ... + 1/R_n$$

Note: ALWAYS convert the values you are working with to the "BASE unit." For example: don't plug kilo-ohms (K $\Omega$ ) into the equation. Convert the value to  $\Omega$  first.

# TURBINE ASSEMBLY

# **Materials for Each Tower:**









1 – 24" length PVC Pipe

1 – 2" length PVC Pipe

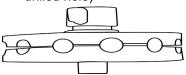
6 - 6" length PVC Pipe

3 - PVC T-Joints (one with a drilled hole)









5 - PVC Elbow (90°) Fittings

1 - PVC Coupler

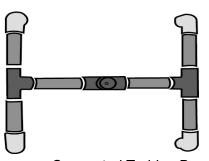
1 – Generator with 4' of wire

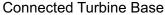
1 – 12 Hole Crimping Hub

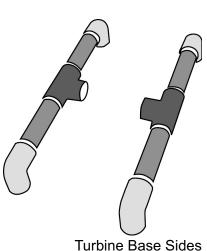
# **Constructing the Base:**

You will need: 4 - Elbow Fittings, 3 - PVC T-Joints, 6 - 6" length PVC Pipe

- 1. Put aside the T-Joint with the drilled hole and two 6" lengths of PVC Pipe.
- 2. Using the remaining materials, follow the diagram on the right to construct the two sides of the turbine base.
- 3. Connect the two sides of the base using the remaining 6" lengths of PVC and the T-Joint with the hole. The drilled hole should be pointing toward the ground.



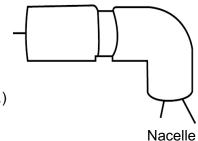




# **Constructing the Nacelle:**

You will need: 1 – PVC Elbow, 1 - 2" length PVC Pipe, 1 – PVC Coupler, 1- Generator with 4' of wire, duct tape (not included)

- 1. Cut a piece of duct tape so it is about 18" long and ½" wide. Wrap the duct tape around the outside of the motor. This will help the motor fit securely into the PVC coupler.
- 2. Connect the PVC Coupler, 2" length of PVC Pipe, and PVC Elbow as illustrated below. This is your nacelle.
- 3. Insert the wires attached to the generator through the nacelle. They should come out of the PVC Elbow fitting.
- 4. Insert the motor into the coupler. It should fit very snuggly. If it is too loose, you can add more tape, if it is too tight you can remove some tape. (Tip: You may want to tape the wires down inside the nacelle to prevent students from breaking them if they pull too hard on the wires.)
- 5. Make sure the generator is straight and not too far in. If it is not straight it will cause the hub and blades to wobble while spinning.



# **Connecting the Tower:**

You will need: 1 – 24" length of PVC, the constructed base, the constructed nacelle

- 1. Thread the generator wires through the PVC tower, then through the whole in the T-Joint at the base.
- 2. Fit the tower into the base.
- 3. Fit the nacelle onto the top of the tower.

# Adding the Hub and Blades:

You will need: 1 – 12 Hole Crimping Hub

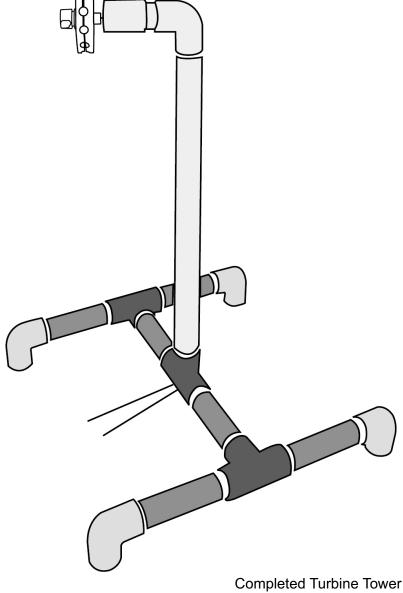
- Attach the hub to the nacelle by pressing it onto the generator's drive shaft.
- Turn the knob on the front of the hub to loosen the two hub sides. Do not turn the knob too far or the hub will separate completely.
- 3. Place the blades into the slots. Tighten the hub to hold the blades in place.

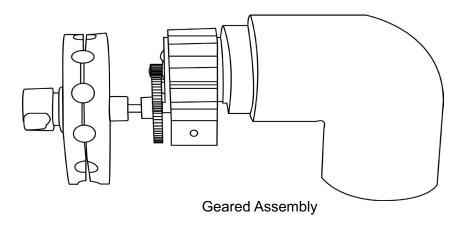
# Converting from a Basic Turbine to a Geared Turbine

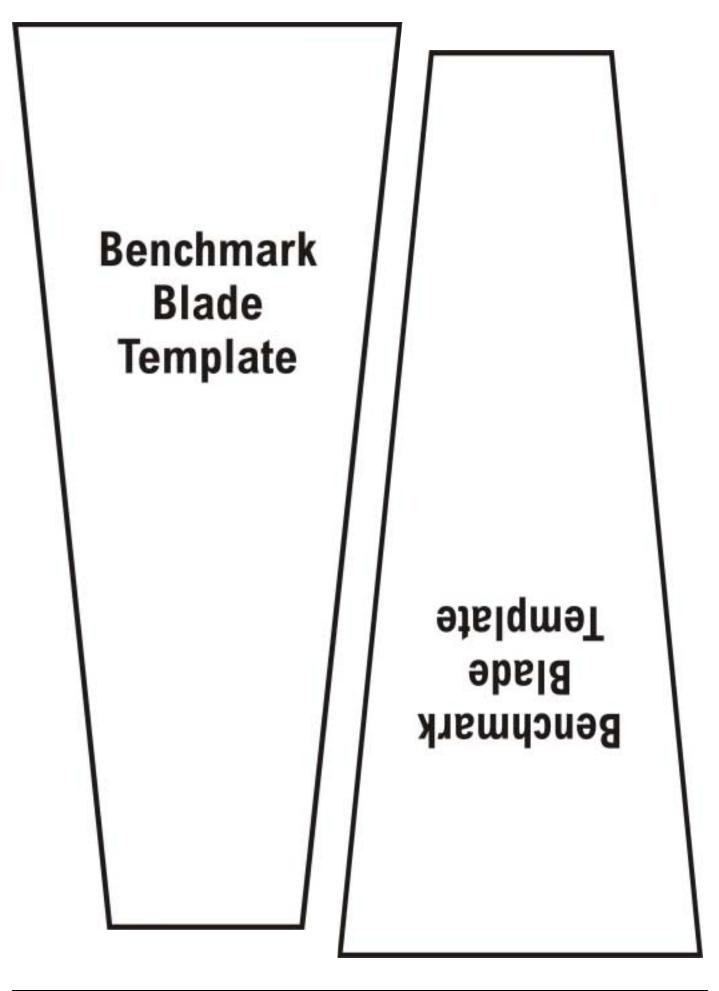
You will need: 1- Geared Assembly

- 1. Remove the hub, basic generator, and wires from the nacelle.
- 2. Thread the geared assembly wires through the nacelle, tower, and out of the T-Joint at the base.
- 3. Fit the geared assembly into the PVC Coupler. It should fit snugly.

Note: The hub on the geared assembly does not come off. Students will need to insert their blades into the hub on the geared assembly.







# 1. EXPLORING BLADE PITCH

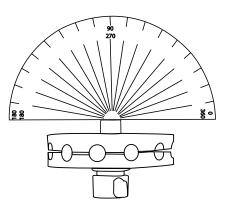
QUESTION: How does the blade's pitch affect the turbine's electrical output? HYPOTHESIS: Make a hypothesis to address the question using the following format: If (manipulated variable) then (responding variable) because ... Manipulated Variable: Blade Pitch Responding Variable: Electrical Output

Controlled Variables:

MATERIALS: Poster board, dowels, scissors, tape, hub, protractor, turbine testing station (turbine tower, multimeter, fan)

#### PROCEDURE

- Using the Standard Blade Design Template, make three blades out of posterboard. Space them evenly around the hub.
- 2. Place the base of the protractor against the back of the hub. Set the blades to a pitch of 90 degrees.
- 3. Put your hub on the turbine tower and observe the results. Record the data.
- 4. Set your blades to a new pitch and test again. This is your second trial. Record your data.
- 5. Repeat Step 4 at least once more to try and find the optimum pitch for greatest electrical output.



#### DATA TABLE:

	Pitch	Electrical Output
Trial 1	90 degrees	
Trial 2		
Trial 3		

GRAPH DATA: The manipulated variable is written on the X axis (horizontal) and the responding variable is written on the Y axis (vertical).

CONCLUSION: Do you accept or reject your hypothesis? Use results from your data table to support your reasoning and explain which blade pitch you will proceed with for your next investigations and why.

Note: The pitch you decided on today will now be a controlled variable. You will continue to use this pitch in the next investigations.

# 2. EXPLORING NUMBER OF BLADES

QUESTION:	How do the number of blades on a turbine affect electrical output?
HYPOTHESIS:	Make a hypothesis to address the question using the following format: If (manipulated variable) then (responding variable) because
•	riable: Number of Blades iable: Electrical Output bles:
MATERIALS:	Benchmark Blades, poster board, dowels, scissors, tape, hub, turbine testing station
PROCEDURE 1.	Decide how many blades you will be testing and make enough blades for the

- maximum number you'll be testing. 2. In the data table put down the results from yesterday's investigation.
- 3. Put the number of blades you want to test into the hub. They should have the same pitch as yesterday's investigation.
- 4. Put your hub onto the turbine tower and test the number of blades. Record the results.
- 5. Repeat steps 3-4 at least two more times to try and find the optimum number of blades for greatest electrical output

# DATA TABLE:

	Number of Blades	Electrical Output
Benchmark -		
3 Blades		
Trial 1		
Trial 2		
Trial 3		

GRAPH DATA: The manipulated variable is written on the X axis (horizontal) and the responding variable is written on the Y axis (vertical).

CONCLUSION: Do you accept or reject your hypothesis? Use results from your data table to support your reasoning and explain how many blades are ideal for a turbine.

Note: The number of blades with the best electrical output along should be the basis for your next investigation.

# 3. EXPLORING SURFACE AREA

QUESTION:	How does the surface area of a wind turbine blade affect electrical output?		
HYPOTHESIS:	Make a hypothesis to address the question using the following format: If (manipulated variable) then (responding variable) because		
	riable:		
Responding Var Controlled Varia	iable:bles:		

MATERIALS: Blades, poster board, dowels, scissors, tape, hub, turbine testing station

#### **PROCEDURE**

- 1. In the data table put down the best results from yesterday's investigation.
- 2. Decide three different blade lengths to test today. Make your new blades. You should have the same number of blades that you found had the best results in your previous investigation.
- 3. Find the surface area for each of your new blade lengths.
- 4. Test each different set of blades, record your results.

# DATA TABLE:

	Surface Area	Electrical Output
Benchmark		
Trial 1		
Trial 2		
Trial 3		

GRAPH DATA: The manipulated variable is written on the X axis (horizontal) and the responding variable is written on the Y axis (vertical).

CONCLUSION: Do you accept or reject your hypothesis? Use results from your data table to support your reasoning and explain how surface area affects the electrical output. Why do you think this is?

Note: The best results from today will serve as your blades for the next investigation.

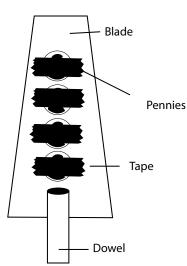
# 4. EXPLORING MASS

QUESTION:	How does adding mass to the blades affect the turbine's electrical output?			
HYPOTHESIS:	Make a hypothesis to address the question using the following format: If (manipulated variable) then (responding variable) because			
Manipulated Var	iable.			
Responding Var				
Controlled Varia				

MATERIALS: Optimum blades from previous investigation, pennies (or other mass), tape, turbine testing station

# **PROCEDURE**

- 1. In the data table record your results from yesterday under the row with zero mass.
- 2. Tape one penny near the base of each blade, an equal distance from the center of the hub
- 3. Test and record the output. Repeat adding another penny. If adding mass incrases the output, add more pennies one at a time until you determine the ideal mass.



# DATA TABLE:

Mass	Electrical Output
0	

GRAPH DATA: The manipulated variable is written on the X axis (horizontal) and the responding variable is written on the Y axis (vertical).

CONCLUSION: Do you accept or reject your hypothesis? Use results from your data table to support your reasoning and explain how mass and mass distribution affect the electrical output. Why do you think this is?

Note: The best results from today will serve as your blades for the next investigation.

# 5. DESIGNING OPTIMUM BLADES

CHALLENGE: The engineers at Wind for Tomorrow Turbine Co. want help to optimize their

turbine blades for higher energy output. They are accepting bids from companies to design blades that more effectively convert kinetic energy than their current

blade design.

EXPLORE: Using data from your previous investigations and data from other groups, explore

ideas for the best blade design.

MAKE A PLAN: Sketch your design, list the materials you will need, and detail the steps you will

take to make the blades. Construct your blades.

DATA: Test and record the electrical output from your new blades. Compare your data to

the benchmark blades in Exploration #1 and your blades in Exploration #4.

DATA TABLE:

Blades	Electrical Output
Benchmark	
Exploration #4 Blades	
1st Design	
2nd Design	

ANALYSIS: How did the output of your blades compare to the output of the benchmark blades

and the #4 blades? Explain why your blade design is more or lest effective than

the comparison blades.

NEW PLAN: Using your data from the data table above, draw and describe specific changes

you will make to your blade to increase its electrical output and why you will make

these changes.

REDESIGN: Using your changes, alter the design of your blades, test, and record your data.

ANALYSIS: How did the outcome of your re-design compare to the output of the benchmark

blades, the #4 blades and your first design? Explain your results.

REPORT: Write a report to the Wind for Tomorrow Turbine Co. detailing your best blade

design. Use data to explain why the company should or should not go with your

design.

# 6. THE EFFECT OF ADDING A GEARBOX

QUESTION: How does a gearbox affect the electrical output of a wind turbine?

HYPOTHESIS: Make a hypothesis to address the question using the following format: If

(manipulated variable) then (responding variable) because ...

MATERIALS: multimeter, fan, turbine, gearbox, optimum blades

#### PROCEDURE:

1. Measure and record the electrical output of the optimum blades using a non-geared turbine.

2. Measure and record the electrical output of the optimum blades using the geared turbine, making sure that you minimize all other variables.

RESULTS: Compare the electrical output of the non-geared and geared turbines. Calculate

the effective gear ratio.

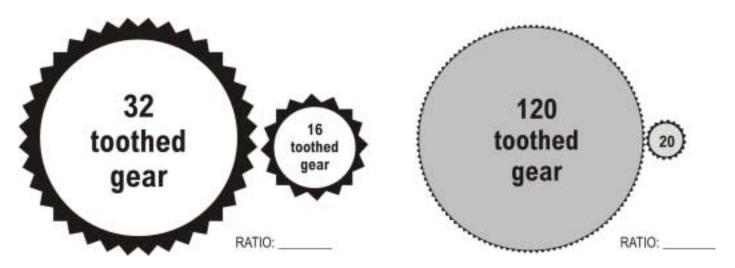
CONCLUSION: The gear ratio of the gearbox is 7:1. How does this compare to your calculated

gear ratio? What factors might explain the difference between the gear ratio of the

gearbox and your calculated gear ratio?

# **EXTENSIONS:**

- 1. Calculate the gear ratios of the gears shown below.
- 2. If the 32-toothed gear and the 120-toothed gear are rotating at 50 rpm (revolutions per minute), how fast are the 16-toothed gear and 20-toothed gear rotating?



# **CALCULATING WIND POWER**

QUESTION: How do you calculate wind power?

MATERIALS: fan, wind gauge, turbine with benchmark blades, meter stick

FORMULA: Power =  $\frac{1}{2} \rho AV^3$ , where  $\rho$  = air density, A = swept area (A =  $\pi r^2$ ), V = velocity ( $\pi$  = 3.1416)

Watts = 
$$\frac{1}{2} \left(\frac{kg}{m^3}\right) \times \left(m^2\right) \times \left(\frac{m}{s}\right)^3$$
 ( $\rho \approx 1.2 \text{ kg/m}^3$  at standard ambient temperature and pressure)

# PROCEDURE:

- 1. Measure the radius of the turbine blade assembly and calculate the area swept by the blades (A = pr2)
- 2. Use the wind gauge to measure the wind velocity at a distance of 1 meter from the fan on low and high speeds. Convert the measurements from miles per hour to meters per second (mps). (1 mile = 1609.344 meter)

Wind Velocity at Low Speed - 1 meter: \_\_\_\_\_ mph = \_\_\_\_mps

Wind Velocity at High Speed - 1 meter: \_\_\_\_\_ mph = \_\_\_\_mps

3. Use the formula above to calculate the power of the wind at both fan speeds.

Wind Power at Low Speed - 1 meter: \_\_\_\_\_W

Wind Power at High Speed - 1 meter: \_\_\_\_\_W

4. Vary the distance from the fan and calculate the power on low and high speeds.

Wind Power at \_\_\_\_\_m (distance A) on Low Speed: \_\_\_\_\_W

Wind Power at \_\_\_\_\_m (distance A) on High Speed: \_\_\_\_\_W

Wind Power at m (distance B) on Low Speed: W

Wind Power at \_\_\_\_\_m (distance B) on High Speed: \_\_\_\_\_W

RESULTS: Compare the power at different distances from the fan and on different fan speeds.

CONCLUSION: Explain the relationships between the different variables and the power produced.

# SITING A WIND FARM: **Roles and Key Questions**

The Bureau of Land Management has received a proposal from a developer to build a wind farm on public land in your community. You understand that developing renewable resources is a way to meet the growing electricity needs of your area, but you are concerned about the impact a wind farm might have on your community. You and other stakeholders have been invited to present your perspectives at a public forum. Based on your research, followed by your panel presentation, the community will vote on whether or not to support building the wind farm.

# Governmental Agency Representative—BLM

The Bureau of Land Management is an agency in the Federal Government that is responsible for managing and conserving the resources that are on public land. The BLM has a policy of encouraging multiple uses of public lands. If a wind farm is built on the public land under your control, you will be responsible for overseeing and managing the project. The federal government would receive lease payments and/or royalties from the developer.

- 1. What are the advantages and disadvantages to the BLM of allowing the development of the wind farm?
- 2. What are the major issues that the BLM must consider before allowing the development of the wind farm?
- 3. One of the jobs of the BLM is to protect the public's interest in the land. Will allowing the development of the wind farm be in the best interest of the public?

# Developer

As the developer of the wind farm project, you must create a plan that details the advantages of establishing a wind farm in your particular area. You must also be able to answer questions from those groups that might oppose the wind farm. It is important as the developer that you understand the "big picture" of the positive and negative impacts of developing the wind farm.

- 1. What are the long-term benefits to the community of developing the wind farm?
- 2. What are the disadvantages? How will potential risks be minimized?
- 3. How will the environment be protected during the installation, operation, and maintenance of the wind farm?

#### Investor

An investor is someone who uses his or her money now to finance a project, in order to make money later. A developer has approached you with a proposal to build a wind farm in a nearby community. As an investor, you are interested in paying money now to build a wind farm, with the idea that you will earn money later as the wind farm becomes productive. You need to determine the costs, risks, earning potential, and benefits of investing in the wind farm.

- 1. How much will it cost to build and maintain the wind farm? What costs do you need to consider?
- 2. How much return of income can you expect from your investment? Over how many years?
- 3. What are the biggest risks to investing in the wind farm?

#### Site Planner

The site planner of a wind farm considers many factors to determine the best location for a wind farm. You must take into consideration the important concerns that community members have. You need to determine the optimum areas for the turbines in regard to local weather patterns. You must also take into consideration any other environmental factors that might affect the siting of the wind farm.

- 1. What information about local and global weather patterns and wind technology must you research before siting a wind farm?
- 2. What environmental factors must you consider before siting a wind farm?
- 3. What other factors must you consider? Are there roads and power lines nearby?

#### Farmer/Rancher

You are a farmer and rancher who has a long-term lease of 10,000 acres of public land that you use to grow crops and graze your cattle. The Bureau of Land Management has informed you that it is considering a proposal to allow a wind farm to be built on part of the land. You think that using renewable energy and having multiple uses of the land are good ideas, but you are concerned about the impact of a wind farm on your crops and animals.

- 1. What impacts will siting, building, and operating a wind farm have on your crops and cattle?
- 2. Will you have to reduce the acres of crops you grow or the number of cattle that graze on the land?
- 3. Are there any benefits to you of building the wind farm on your leased land?

# Consumer/Neighbor

You are a neighbor of the farmer/rancher on whose land the wind farm might be built. You have heard that large wind turbines generate a great deal of noise and that concerns you because the chinchillas you raise are very sensitive to noise. You are aware that there have been predictions of blackouts in the near future in your area because of a lack of electricity capacity. You are also wondering how the price of electricity in your area might be affected if a wind farm were installed.

- 1. How much noise do wind turbines generate?
- 2. How would a wind farm affect the property values of the surrounding properties?
- 3. How would local electricity rates be affected by the installation of a wind farm?

#### Environmentalist

You are very concerned with protecting the environment. You would like to know how wind energy impacts the environment during the manufacture, installation, maintenance, and removal of the wind turbines. Also, there have been reports in the past of wind turbines injuring birds and bats that fly into them. You would like to know how wind energy installations might affect birds and animals in your area.

- 1. How would the manufacture and installation of wind turbines affect the local environment?
- 2. How would the operation of the wind turbines affect the surrounding environment and the plants and animals in the area?
- 3. Would the amount of electricity generated by the wind turbines be enough to offset the 'cost' to the environment?

# **Economist**

An economist is a person who can analyze the financial impacts of actions. The community that will be affected by the development of the wind farm has consulted you. They have asked you to determine the costs of generating electricity from fossil fuels and wind energy and to do a comparison study. This includes comparing construction costs, transmission costs, generation costs, and potential tax credits available for using wind.

- 1. How does the cost of using wind to generate electricity compare to other sources?
- 2. What economic advantages/disadvantages would the wind farm bring to the area?
- 3. Will the wind farm impact the economy of the area by bringing more jobs to the area?

# Utility Company Representative

You are an employee of the local utility company and are responsible for making sure that your utility has the necessary capacity to provide electricity to all of your customers. There is increased demand for electricity in your community and you know you must secure reliable sources of additional generation in the near future. You would be the main purchaser of electricity from the wind farm.

- 1. How expensive would the electricity be from the wind farm?
- 2. Will the wind farm produce enough electricity with reliability to meet the growing needs of the community?
- 3. Will there be additional costs to the utility company that might be passed along to consumers?

# Member of the County Commission

The County Commission manages the public services of the community and determines how they are paid for. The County Commission is a political group and must take into consideration all political sides of the issue. You must consider the impacts on the community if the BLM allows the wind farm to be developed in the area.

- 1. What impacts would the wind farm have on the need to provide local services?
- 2. What economic impacts would the wind farm have on the local community and taxes?
- 3. What political impact would supporting the wind farm have on your community?

# Useful sites to visit when conducting research:

American Wind Energy Association:

www.awea.org

The Energy Information Association:

www.eia.doe.gov

Energy Kid's Page

www.eia.doe.gov/kids

**Bureau of Land Management:** 

www.blm.gov

U.S. Department of Energy's Energy Efficiency and Renewable Energy:

http://www1.eere.energy.gov/windandhydro/

# **EXPLORING WIND ENERGY**

# **Evaluation Form**

S	tate: Grade Level: N	umber of Students:	
1.	Did you conduct all of the activities? If no, why not?		
2.	Were the instructions clear and easy to follow?	Yes N	No
3.	Did the activities meet your academic objectives?	Yes N	No
4.	Were the activities age appropriate?	Yes N	No
5.	Were the materials easy to use?	Yes N	No
6.	Were the students interested and motivated?	Yes N	No
7.	Was the energy knowledge content age appropriate?	Yes N	No
8.	Would you use the activities again?	Yes N	No
9.	Did you like having the student work pages in the Tea	cher Guide? Yes N	No
10.	Prior to this unit had you used science notebooks?	Yes N	No
11.	Did you use the science notebook pages built into the	Yes N	No
	Student Guide?		
How v	vould you rate the unit overall (excellent, good, fair, po	or)?	
How v	vould your students rate the unit overall (excellent, god	d, fair, poor)?	
What	would make the unit more useful to you?		

Would you like to share the story of how you used this unit in your classroom with other teachers? How did your students benefit from these activities? What extensions did you create to continue student learning? If so, please give us your contact information so we may highlight your story in a future Energy Exchange newsletter.

Please fax or mail to:

**NEED Project** PO Box 10101 Manassas, VA 20108 FAX: 1-800-847-1820

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